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Teachers' pedagogical content knowledge and new structures for subject matter content

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Abstract

This paper examines the concept of pedagogical content knowledge and its implications for teacher preparation and student's learning. The main part of this paper will focus on the necessity of structuring the subject matter in such a way that the content becomes teachable to students. Studies will be presented to analyze different subject matter structures that can be used to make the content accessible to students.

Teacher' Pedagogical Content Knowledge and New Structures for Subject Matter Content

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TABLE OF CONTENTS

Introduction

This paper examines the concept of pedagogical content knowledge and its implications for teacher preparation and student's learning. The main part of this paper will focus on the necessity of structuring the subject matter in such a way that the content becomes teachable to students. Studies will be presented to analyze different subject matter structures that can be used to make the content accessible to students.

Research Question

Although many efforts have been made to help all teachers become better teachers, unanswered questions arise concerning how teachers can improve student learning.

- What do teachers need to know to improve student learning?
- How can we define and understand the necessity of structuring the subject matter to make it comprehensible to all students?
- What attempts have already been made to organize the content so that it becomes teachable to diverse students in a classroom?

Purpose of the Paper:

The purpose of this research paper is to identify and analyze the knowledge that an expert teacher needs to have in order to be successful in the classroom and adjust the content taught to diverse learners. In order to do this the paper investigates the development of the

idea of pedagogical content knowledge, focusing mostly on Shulman's framework. The discussion analyzes the necessity of pedagogical content knowledge and its benefits for student learning. The strong necessity to combine content with pedagogy is emphasized. The research that this paper provides will help teachers see why it is important to understand the structure of subject matter and how can it be made teachable to students.

An examination of recent research on teaching and teacher education indicates that the concept of content knowledge is perhaps too broad of a topic. It can be better understood by breaking it down into several components, examining each separately, and analyzing their interrelationships. The literature shows that the concepts "Subject Matter Knowledge, Pedagogical Knowledge, Curricular Knowledge and Pedagogical Content Knowledge" describe and distinguish the kinds of knowledge that teachers must utilize to successfully engage students in meaningful learning experiences. This subdivision works to most clearly distinguish the act of teaching as something significantly more complicated than the mere transmission of facts, figures, names, dates, and places that expert teachers need to know.

This paper is organized as follows. Chapter I discusses the purpose of this paper and the context of knowledge based elements in which pedagogical content knowledge fits. Chapter II reviews the literature concerning the definitions of pedagogical content knowledge according to several theorists, including Shulman, Veal, and Grossman. Thus this section will provide a history of pedagogical content knowledge by defining the same tern from different theorists' perspectives.

Chapter III is concerned primarily with the contributions of Pedagogical Content Knowledge to teachers' preparation. It also looks for the elements of Pedagogical Content Knowledge that are directed toward fostering students' learning. This review covers literature through 1986- 2001. The references that I am going to use include names like: Grossman, P.

L., Stodosky, S., Holmes Group, Bellanca, J., Schon, Schwab, J., Linda- Darling Hammond, Woolfolk, A., Gudsmundottir.

Chapter IV summarizes recent research that made attempts to implement Pedagogical Content Knowledge and see how it works in the classroom and colleges.

Chapter V addresses what the research says, draws conclusions based on that research, explains how the research affects what we know and concludes on what we should think about teaching.

Shulman (1987) said expert teachers need an extensive knowledge of the academic subjects they teach. They also need general teaching strategies that apply to all subjects (such as the principles of classroom management, effective teaching, and evaluation); curriculum materials and programs should be appropriate for the subjects and grade levels. And teachers need subject- specific knowledge for teaching that is special ways of teaching certain students and particular concepts, such as the best ways to explain negative numbers to lower-ability students, the characteristics and cultural backgrounds of learners, the settings in which students learn (pairs, small groups, teams, classes, schools, and the community); the goals and purposes of teaching.

This paper will be concerned with an in-depth description of different models and taxonomies for structuring the subject matter so that the content becomes comprehensible to all students.

An emphasis will be placed on the teacher as a thinking, evaluative professional who takes action within an environment that changes socially, economically, technologically and professionally.

Definitions of Knowledge Base Elements:

Shulman (1987) in his article "Knowledge and Teaching: Foundations of the New Reform" outlines the categories of knowledge that underlie the teacher understanding needed to promote comprehension among students. These categories include: pedagogical content knowledge, content knowledge, curriculum knowledge, general pedagogical knowledge, knowledge of learners and their characteristics, knowledge of educational contexts and knowledge of educational ends.

Pedagogical Content Knowledge

Shulman (1986) first proposed pedagogical content knowledge and developed it with colleagues in the *Knowledge Growth in Teaching* project as a broader perspective model for understanding teaching and learning (Shulman & Grossman, 1986). This project studied how novice teachers acquired new understandings of the subject content and how these new understandings influenced their teaching. Shulman and Grossman described pedagogical content knowledge as "an understanding of how particular topics, problems, or issues are organized, presented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (1987, p. 8). Shulman also suggested that pedagogical content knowledge was the essential knowledge base of teaching:

> The key to distinguishing the knowledge base of teaching lies at the intersection of content and pedagogy, in the capacity of a teacher to transform the content knowledge he or she possesses into forms that are pedagogically powerful and yet adaptive to the variations in ability and background presented by the students. (p. 15)

According to Gudmunsdottir (1995),

> Pedagogical content knowledge is a practical way of knowing the subject matter. It is learned mostly on the job from trying things out and observing, talking, and working with other teachers. Tradition provides the narrative models to draw upon to understand and construct the present, and it is maintained by the sense of accumulated practice that is also shared by others. (p. 6)

Teachers live in stories. They use them to tell their students about some of the things they know. When researchers offer themselves to teachers as sympathetic listeners, they can learn from teachers about who they are, what they know, and their world in the classroom. As researchers probe and guide with their questions, the teachers' stories inevitably become a joint production. This process is a dynamic one. Past experiences are not buried in the ground like archeological treasures waiting to be recovered and studied. Rather, the past is recreated through telling (Gudmundsdottir, 1992). It is through this narrative dialogue of reflection and interpretation that experience is transformed into pedagogical content knowledge. The study of teachers' stories and narratives brings us right to the heart of pedagogical content knowledge, in all its variety and richness. Such a study should focus on the four dimensions of narratives within pedagogical content knowledge: practical experience, interpretation, reflection, and transformation (Shulman 1987).

Content Knowledge

Borko & Putnam (as cited in Schoenfeld, 1998) reported that teacher's knowledge of subject matter knowledge is:

> more than just the facts, terms, and concepts of a discipline. Their knowledge of the organizing ideas, connections among ideas, ways of thinking and arguing, and knowledge growth within the discipline is an important factor in how they will teach the subject. (p. 676)

Darling-Hammond (2001) reports that there are studies of under-prepared teachers that revealed that these teachers most commonly have a hard time with curriculum development, classroom management, student motivation, and teaching strategies. Lacking the basic knowledge about children learning and development, or about how to support their learning, these teachers are unable to comprehend different learning styles. Additionally they can't easily anticipate students' knowledge and potential difficulties, or to plan and redirect instruction to meet students' needs.

"They are also less likely to see it as their job to do so, often blaming the students if their teaching is not successful. Thus, policies that resolve shortages by supporting the hiring of unprepared teachers serve only to exacerbate the inequalities low-income and minority children's experience." (p. 1) (paraphrase this)

Knowledge of Learners and their Characteristics

When students do not learn with complementary resources they do not achieve what they are capable of achieving. Complementary sources include textbooks, films, or videotapes for visual preference; manipulatives for tactual preferences; tapes or lectures for auditory preference; or large floor games for kinesthetic preference. Research has revealed the importance of adjusting learning styles to the learner. In addition, the closer the match between students' learning styles and their teachers' teaching styles, the higher the grade point average. (Dunn, R., Griggs, Olson, Gorman, & Beasley, 1995)

Knowledge of Educational Context

They range from the workings of the group or classroom, the governance and financing of school districts, to the character of communities and cultures. To a large extent, the social, cultural, economic, and political contexts in which educators work, shape the specific content and methods they choose.

When talking about educational context we have to take into consideration several things, such as: population characteristics and trends, children living in low-income situations, and educational attainment of the adult population

Knowledge of Educational Ends

It refers to knowledge of educational aims, goals, purposes, and values, and their philosophical and historical grounds.

Eisner says that aims are the most general statements that proclaim to the world the values that some group holds for an educational program. The advantage of setting aims is that we sense a direction, a point of view, a set of values, to which the community subscribes. ("The aim of this school is to help students learn to participate effectively in a democratic way of life"). The aims provide an articulation of the educational faith.

Goals represent intended outcomes or results. They are statements of intend, midway between aims and objectives. Goals describe the purposes held for a course or school program: ("The goal of this course is to develop skills in copper enamel jewelry making").

Wiles, J. says that goals can be stated in terms of instructional or behavioral outcomes. Goals are considered more specific than aims, but insufficiently specific for instructional objectives. Goals are intended to provide a greater focus on anticipated outcomes and to provide curriculum planners with the basis for the selection of curriculum content. The

scope of the educational programs can be easily determined from the goal statement. Sometimes goals are found in the form of belief statements that serve to define a philosophy or core value.

Chapter II
Review of the Literature

Definitions of Pedagogical Content Knowledge

Pedagogical content knowledge has been introduced in many of the recent educational reform documents to describe the knowledge that expert teachers possess.

Schulman's Definition

Shulman introduced the concept of pedagogical content knowledge in the lexicon of research on teaching in 1986 to illustrate a distinctive, subject-centered feature of the knowledge base of teaching. As the first to propose this concept, he developed it with colleagues in the Knowledge Growth in Teaching Project as a broader perspective model for understanding teaching and learning. This project studied how novice teachers acquired new understandings of subject content, and how these new understandings influenced their teaching.

Shulman and others described pedagogical content knowledge as the knowledge formed by the synthesis of three knowledge bases: subject matter knowledge, pedagogical

knowledge, and context knowledge. Pedagogical content knowledge was unique to teachers and separated for example a science teacher from a scientist.

Along the same lines, Cochran, King, and DeRuiter (1991) differentiated between a teacher and a content specialist in the following manner:

> Teachers differ from biologists, historians, writers, or educational researchers, not necessarily in the quality or quantity of their subject matter knowledge, but in how that knowledge is organized and used. For example, experienced science teachers' knowledge of science is structured from a teaching perspective and is used as a basis for the construction of new knowledge in the field. (p. 5)

Pedagogical content knowledge has also been viewed as a set of special attributes that helped teachers to transfer the content knowledge to others. Shulman (1987) said that subject matter included the "most useful forms of representations of these ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations- in a word, the ways of representing and formulating the subject that make it comprehensible to others" (p. 9). Further Shulman (1987) stated that pedagogical content knowledge included those special attributes a teacher possessed that helped him/her guide a student to understand content in a manner that was personally meaningful.

Shulman wrote that pedagogical content knowledge included "an understanding of how particular topics, problems, or issues are organized, presented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (1987, p. 8). Shulman (1987) also suggested that pedagogical content knowledge was the best knowledge base of teaching:

> The key to distinguishing the knowledge base of teaching lies at the intersection of content and pedagogy, in the capacity of a teacher to transform the content knowledge he or she possesses into forms that are pedagogically powerful and yet adaptive to the variations in ability and background presented by the students. (p. 15)

Cochran, King and DeRuiter

Cochran, King and DeRuiter (1991) defined pedagogical content knowledge as "the manner in which teachers relate their pedagogical knowledge to their subject matter knowledge in the school context, for the teaching of specific students (p. 1). This definition incorporated four components: knowledge of subject matter, knowledge of students, knowledge of environmental contexts, and knowledge of pedagogy. They used two Venn diagrams to show how the four components overlapped and how pedagogical content knowledge was centralized within the overlaps. The first diagram represented the integration of the four components in a novice teacher. The second larger diagram represented the integration of the four components of an experienced teacher symbolizing the "extra knowledge" gained from years of experience. Another difference in the two Venn diagrams was the amount of overlap between the four components. The Venn diagram for the experienced teacher showed greater overlap, symbolizing increased integration of the four components, thus greater pedagogical content knowledge development.

Magnusson, Krajcik, and Borko

Magnusson, Krajcik, and Borko conceptualized pedagogical content knowledge for science teaching and said it consisted of five components. The first one was a teacher's orientation toward science teaching, which consisted of a teacher's beliefs about the purposes and goals for teaching science at different grade levels. These beliefs were the basis of a conceptual map that guided the teacher's instructional decisions. The second component was called science curriculum knowledge which represented the knowledge about the goals and

objectives of the curricula (state, national, and vertical) and about specific curricular problems.

Grossman's Four Categories

Grossman's (1990) pedagogical content knowledge contained four major categories of components:

> (1) the teacher's overarching conception of the purposes for teaching a subject matter . . . the nature of the subject and what is important for students to learn;
>
> (2) knowledge of students' understandings and potential misunderstandings of a subject area . . . [including] preconceptions, misconceptions, and alternative conceptions about topics such as division of fractions, negative numbers. . . . ;
>
> (3) knowledge of curriculum and curricular materials; and
>
> (4) knowledge of strategies and representations for teaching particular topics. (p. 676-677)

Veal's Taxonomies

Veal (1997) wrote two taxonomies that offered a relatively comprehensive categorization scheme for future studies of pedagogical content knowledge and addressed the role of pedagogical content knowledge in science teacher development. The first taxonomy is

called the General Taxonomy of Pedagogical Content Knowledge, addressed the distinctions within and between the knowledge bases of various disciplines, science subjects, and science topics. This taxonomy identified the various components of pedagogical content knowledge and characterized their relative importance based on previously published studies.

Veal's General Taxonomy of PCK was organized hierarchically. This taxonomy described general teaching or pedagogical skills that all teachers should develop. These pedagogical skills included: planning, teaching methods, evaluation, group work, questioning, wait time, feedback, individual instruction, lecture, demonstration, and reinforcement. These strategies were not related to any specific content area and could be used across content areas. Pedagogy becomes a component of PCK only when it is specified within the parameters of educational content areas.

General PCK

The first level Veal specified within this taxonomy is General PCK. It is implied that an experienced or expert teacher with general PCK would have a sound understanding of pedagogical concepts. General PCK is more specific than pedagogy, because the concepts and strategies employed are specific to the disciplines of science, art, history, math, or English. General PCK is the same as what Magnusson, Krajcik, and Borko (in press) called subject-specific PCK strategies, where subject meant the content area of science. However, restructuring and renaming this category will serve to clarify the use of PCK in educational research.

Domain-specific PCK

Domain-specific PCK was a more distinct term than General PCK, because it focused on different domains or subject matters within a particular discipline. For example, if chemistry was the subject matter, then an understanding of how to teach it to students would

be characteristic of a teacher who have developed domain-specific PCK. Veal positioned domain-specific PCK between disciplines and domains of science to represent a different level and specificity of subject matter and pedagogy. For example, a performance-based laboratory in chemistry might use chemicals and titration pipettes, whereas a performance-based laboratory in biology might involve dissecting a shark. Both activities involve the laboratory within the disciplines of science, but the individual tools and purposes are specific to the subject matter or domain. Magnusson, Krajcik, and Borko (in press) referred to this type of PCK as topic-specific.

Topic-specific PCK

The most specific and novel level of the Veal's general taxonomy is topic specific PCK. Theoretically, a teacher with knowledge on this level of PCK would have a solid repertoire of skills and abilities in the previous three levels. Each domain, or subject of science has its own list of concepts, terms, and topics, some of which overlap (e.g., Magnusson & Krajcik, 1993). Although the concepts unique to each domain may be taught differently, the common concepts across subjects are also taught differently on many occasions. For example, thermodynamics is a common concept found in physics and chemistry, would typically be introduced differently in the different domains. The corresponding laboratories and demonstrations are different, as well as the relevant examples used in each textbook. In chemistry, burning a peanut is a laboratory experiment that demonstrates heat content. This experiment can be found in various chemistry textbooks and laboratory books. However this same laboratory would almost never be found in physics textbooks or laboratory manuals. As another example, when discussing heat and temperature, a chemist might use the kinetic molecular theory to describe temperature. Whereas the physicist might say that temperature would just measure heat lost or gained in a system. Even

though each concept explored can be found in both domains, the teaching styles, methods, and approaches to representing these topics usually differed. These differences legitimated the need for developing topic-specific PCK as an instructional paradigm for prospective science teachers.

Chapter III

The Contributions of PCK to the Teacher's Professional Preparation

"Pedagogical content knowledge differentiates expert teachers in a content area from content area experts" according to Shulman (as cited in Ball & McDiarmid). Novice teachers often cannot transform their subject matter knowledge effectively for the teaching/learning environment and instead rely on subject matter knowledge taken from a text, commercial curriculum materials, or authoritative knowledge sources, without considering appropriate pedagogical practice. Shulman said transformation of novice teachers to expert teachers occurred as the individual critically reflected on and interpreted the subject matter; found multiple ways to represent the information through analogies, metaphors, examples, problems, demonstrations and classroom activities. Novices also learn to adapt the material to students' abilities, gender, prior knowledge, and preconceptions, and, finally to tailor the material to specific students (Shulman, as cited in Ball & McDiarmid, 1990, p.1).

"Teaching that ensures increased levels of success for all students demands academic mastery on the part of teachers, thereby providing teachers with the capacity to help students make the connections between what they know and new concepts, information, or skills they need to acquire. However, equally important, and directly linked to the quest for

increased content knowledge, is the impact of research on pedagogical content knowledge and its role in teacher effectiveness. Although educators must first deeply comprehend their content, they must also transform content for teaching purposes in ways that make it accessible and meaningful to students. This transformation of content occurs as educators critically reflect on and interpret content and determine appropriate instructional representations. This transformational, pedagogical content knowledge differentiates "expert teachers" in content fields from "content area experts" (Reflecting upon and refining best practices: professional knowledge and skills to develop a repertoire of instructional and assessment strategies).

According to Redish and Shulman as cited in Bransford (2000) there is a clear distinction between the content knowledge necessary for expertise in a discipline and the content knowledge necessary for effective teaching. Pedagogical content knowledge "includes information about typical difficulties that students encounter as they attempt to learn about a set of topics; typical paths.

The relationship between PCK and student learning

Darling- Hammond (1997), in her article entitled "Quality Teaching: The Critical Key to Learning" discussed the challenges that today' s educators face and which are greater than ever before. "To meet the needs of the 21st century, America's teachers are being asked to teach students with vastly different experiences, language backgrounds, cultures, talents, and needs to master more challenging content, and to do so far more effectively than they have ever done before" (Darling- Hammond, 1997, p. 2). "Teaching diverse learners to master

more complex skills and more challenging content is much more difficult than teaching for simple recall or low- level basic skills" (p. 2).

"Expert teachers know the structure of the knowledge in their disciplines. This knowledge provides them with cognitive road maps to guide the assignments they give students, the assessments they use to gauge student progress, and the questions they ask in the give-and-take of classroom life. Expert teachers are sensitive to the aspects of the subject matter that are especially difficult and easy for students to grasp: they know the conceptual barriers that are likely to hinder learning, so they watch for these tell-tale signs of students' misconceptions. In this way, both students' prior knowledge and teachers' knowledge of subject content become critical components of learners' growth " (Bransford, et al, 2000, p. 241).

Shulman (as cited in Bransford et al., 2000) stated that pedagogical content knowledge is not the same thing as knowledge of a content domain plus a generic set of teaching strategies. He said that teaching strategies are totally different from one discipline to another. " Expert teachers know the kinds of difficulties that students are likely to face; they know how to tap into students' existing knowledge in order to make new information meaningful; and they

Teachers need to understand the structure of their subject matter to identify generative topics and to define goals to understand how to teach disciplines.

Chapter IV

Studies that investigate Pedagogical Content Knowledge

Murray (1998) in his article *Reforming teacher education: issues and the joint effort of education and liberal arts faculty* talks about reforming teacher education and strongly emphasized the use of pedagogical content knowledge in teacher preparation programs. He described the efforts that a group of institutions (Project 30) made to create a relationship between education and the liberal arts. Murray discusses the uses of a liberal arts education in teacher preparation, how academic disciplines are converted into school lessons and how the curriculum can be changed to be more effective. The solution that Project 30 institutions found was to develop a set of approaches housed the teacher preparation programs, and these included pedagogical content knowledge. The full set of Project 30 approaches were: interdisciplinary majors, philosophy of subject matter, text approaches, genetic epistemology, cognitive psychology major, and pedagogical content knowledge.

When talking about pedagogical content knowledge, Project 30 tried to find out what pre-service teachers should learn about transforming subject matter into a teachable subject for a diversity of students in a classroom. Researchers involved learned that subjects need a new meaning and different structure so students could perceive and understand them. These structures could be studied and codified. "Since this reformulation of the discipline is inevitable in teaching, one might as well address it directly and, as in other approaches, use it as a way to structure the academic disciplines" (Murray, 1998, p. 5). Murray gave the example of teaching *Huckleberry Finn*. The teachers usually interpreted the book as a story of race relations, generation gaps, an historic period, or latent homosexuality on the frontier. As another example, when describing electric current science teachers usually compared electric current with the behavior of water current in various sizes of pipes. The researchers questioned whether this method was the best way to think about electricity. They concluded

that the answer to this can't be found in physics or in education, but "in a qualitatively different kind of knowledge that will come from conversations between disciplinarians and pedagogues" (Murray, 1998, p. 5). That is why Murray (1998) stated that "this knowledge the knowledge of what is a telling example, a good analogy, a provocative question, or a compelling theme- is a proper object of study and could yield a deep and generative understanding of the discipline" (p. 5). He explained this information could help teachers find many ways of presenting a subject, provide a variety of examples or metaphors to illustrate one topic or gain several modalities of explanation. All required a deep understanding of the subject matter.

Murray wrote that the central idea of the article is the necessity of structuring the subject matter so that students understand it easily. "The knowledge that supports this conversion of the storehouse of knowledge into the school curriculum, into something that has meaning for the pupil, is what is meant by the expression, pedagogical content knowledge, or the lesson" (Murray, 1998, p. 7). According to Murray (1998), even if the teacher does not provide any structure to the discipline, all the students will strive to find ways or schemes to organize it in certain ways because creating a mental or physical structure of the information is how the human mind actually works. He stated:

> The question is never whether or not there was some structure, theory, scheme, etc., but only whether the structure was good or poor. Whatever the teacher actually did in the lesson, the students will find some way to make sense of it, to code it, to assimilate it into what they already know often with an outcome the teacher may never have intended (p 7).

To illustrate this desire to organize and structure information, Murray used the example of the universal error students make when they mistaken Martin Luther King for

Martin Luther. He said students are trying to make sense of what the teacher is presented. That is why learners can reduce pedagogical content knowledge to the appropriate ways of organizing information and knowledge. "It is the search for structures, ways of representing the subject matter, analogies and metaphors, that will take each pupil well beyond what can be held together temporally and spatially through rote memorization." (Murray, 1998, p. 8)

Selecting the structure used to represent the knowledge is not just a matter of the content itself, but also of the characteristics of the students who need to acquire this knowledge.

Another article entitled " Charting the Links Between Mathematics Content and Pedagogy Concepts: Cartographies of Cognition" (Von-Minden, 1998) discussed the links between content knowledge in the mathematical domain and in pedagogical reasoning. The author conducted a study to see how mathematics teachers organized the conceptual relationships of content and the relationships of pedagogical concepts. Most importantly, he wanted to see how these teachers made the connections between content and pedagogy. Shulman (as cited in Von-Minden, 1998, p. 2) stated that content knowledge and pedagogical strategies had to interact in the minds of teachers. "That synthesis of content and pedagogy is teachers' special form of understanding that facilitates good teaching for effective learning." Von-Minden, then, based his study on Shulman's assumption of good teaching which stated, it is " the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners and presented for instruction" (Shulman, as cited in Von-Minden,1998, p. 2).

Van-Minden discussed the Shulman and Quinlan article entitled "The Comparative Psychology of School Subjects" in which they emphasized the importance of having

pedagogical content knowledge specific to the subject matter. This meant that a teacher who taught both mathematics and social studies used subject-specific strategies to teach one or the other. In other words, a teacher's knowledge of specific content was necessary prerequisite to good teaching, "but without pedagogical content knowledge specific to the subject matter, instruction is less effective"(Von-Minden, 1998, p. 2).

A study conducted by Counts (1999) entitled *A Case Study of Physics Professor's Pedagogical Content Knowledge* investigated the case of a single college physics professor who was using pedagogical content knowledge. The researcher looked at the characteristics of this professor's pedagogical content knowledge that are useful in the teaching of any physics course. The results of this study revealed that this college professor was in a large part congruent with Shulman' s conceptualization and Grossman' s components of pedagogical content knowledge. Six categories emerged that described the development of his pedagogical content knowledge: (a) the need for content knowledge, (b) the need for communication, (c) sensitivity to the students' in- class behavior and environment, (d) personal reflection regarding the classroom environment, both before and after class, (e) teaching experience, and (f)collegial discussions about teaching.

Models Illustrating Subject Matter Structuring

The pedagogical models described below combine content and pedagogy in a meaningful and efficient way to show ways of structuring subject matter knowledge. They include a process for teachers to segment and structure content to make it accessible to all students. At the same time, each model facilitates a range of pedagogical strategies that communicate content to the students. Researchers have described different types of pedagogical structures.

"Semantic proximity techniques" such as "word association and similarity-judgements tasks" (Fenker et al. as cited in Von-Minden, 1998) were the first attempts to help teachers structure their subject matter. Similarity-judgements referred to the fact that all possible pairs of concepts are presented and participants were asked to assess the degree of similarity between each presented pair. Those interconcept distances have been analyzed by cluster analysis or by a form of multidimensional scaling such as pathfinder analysis.

Another model to structure knowledge is the use of "concept maps" (Novak & Gowin, as cited in Von-Minden, 1998, p. 2). Concept maps were used to assess synthetic and integrative thinking. Concept maps allowed the user to show "both hierarchical (inclusive) and web-like horizontal (comparative) links" (Beyerbach, Smith & Thomas, as cited in Von-Minden, 1998, p.2). The constructive, generative mapping process has the advantage of allowing "consideration among concepts presented simultaneously" (Goldsmith, Johnson&Acton, as cited in Von-Minden, 1998, p. 3).

Veal's (2000) study entitled "The Evolution of Pedagogical Content Knowledge in Prospective Secondary Chemistry Teachers" compared two types of knowledge: craft knowledge and pedagogical content knowledge. Craft knowledge and pedagogical content knowledge were combined to form the lenses to analyze how secondary chemistry teachers learned to teach.

Many similarities between craft knowledge and pedagogical content knowledge appeared. Craft knowledge revealed the practical aspect of teaching and viewed teaching as a craft. The teacher was the one who possessed the knowledge of teaching. Shulman, when presenting pedagogical content knowledge revealed the same idea by calling it "learning to teach" which meant that the knowledge of teaching belonged to the teacher. Another commonality to craft knowledge and pedagogical content knowledge is the idea that the

teacher understands more about teaching through reflection based upon actual practice. The third common feature is the concept of time. Efficient and effective teaching takes time. Another common aspect of craft knowledge and pedagogical content knowledge is the contextual nature of each knowledge base. The contextual aspect suggested that "teachers have a certain knowledge, range of skills and proficiencies, and representations of the subject matter so that subject matter can be delivered to the students in the best possible manner" (Veal, 1998, p. 5).

Veal analyzed the aspects of learning to teach science through these two frameworks: craft knowledge and PCK. He followed two pre-service chemistry teachers and observed their development through a science curriculum class and their student teaching experience in the teacher preparation program. He monitored the subjects' development of pedagogical content knowledge was monitored using content specific, situational vignettes. The vignettes were administered over a period of time to monitor cognitive change. Data were collected and analyzed using a modified qualitative content analysis. This study validated three major findings about the pre-service chemistry teachers' development of pedagogical content knowledge. First, Veal found that pre-service teachers developed different kinds of pedagogical content knowledge. Second the pre-service teachers developed topic-specific pedagogical content knowledge before domain-specific pedagogical content knowledge. Third, the pre-service teachers showed and developed "foundational understanding of science teaching and learning that will serve as a building block for further development of domain-specific pedagogical content knowledge" (Veal, 1998 p. 5).

In a study entitled "Redefining Teacher Excellence", Collinson (1999) revealed a triad of professional knowledge that exemplary secondary school teachers seemed to develop. After analyzing a sample of 81 secondary school teachers, Collision concluded that they

developed three main kinds of knowledge needed to facilitate students' learning. Pedagogical content knowledge was defined as professional knowledge and it encompasses the knowledge of subject matter, curricular knowledge and pedagogical knowledge. The second kind of knowledge was interpersonal knowledge, the relationships with students, the educational community, and local community. The third knowledge was called intrapersonal knowledge. It incorporated teachers' ethics and dispositions. Basing his research on Shulman's theory of pedagogical content knowledge, Collision found that the three kinds of professional knowledge are a strong, vital element of teacher's expertise.

Chapter V

Conclusions:

The essence of pedagogical content knowledge is for the teacher to develop a variety of structures and choose an appropriate one to accommodate students' individual characteristics. Using these structures, the teacher is able to share content with the students in a way that increases the probability that the students will deeply understand and be able to use the content. Additionally, the teacher should know which structures are more likely to overcome the typical difficulties that students encounter when they acquire new knowledge.

The transmission of knowledge is one of the goals of public education. Teachers are central to this process since the goals are realized through. Yet, it is not enough for teachers to know their subject matter; they also need to know how to teach it.

Pedagogical content knowledge draws on a range of ideas that relate to students, curricular materials, educational contexts, and in particular content and pedagogy. It includes

both general and topic-specific strategies. Pedagogical content knowledge is the most important part of the knowledge base of teaching and distinguishes the veteran teacher from the novice, and the teacher from the scholar.

Making content knowledge pedagogical means a reorganization that focuses on an orientation by discipline. The case studies we analyzed in this research paper show that teachers are striving to find ways to communicate their discipline orientation to their students.

The General PCK Taxonomy and the Taxonomy of PCK Attributes provide a relatively comprehensive categorization for future studies of PCK development in teacher education. The continued interest in PCK as an epistemological category and as a knowledge base for science teacher preparation has produced a need for a conceptual framework upon which future PCK studies can be based. The taxonomies in this paper provide such a framework. First, the General Taxonomy of PCK will allow researchers and teacher education programs to more accurately identify and address distinctions among knowledge bases of various educational disciplines, science subjects, and science topics. In other words, it will provide a classification scheme for implementing unique instructional methods in the science classroom. Second, the Taxonomy of PCK Attributes will enable researchers studying knowledge development in teachers and teacher education programs to identify and characterize different attributes of science teaching. In addition, this taxonomy recognizes the relative importance that researchers and educators have given to the different components of PCK. These types of organizational frameworks will serve to organize and integrate research efforts centered around PCK.

The use of these taxonomies as a foundation for future research will also provide a model for science teacher preparation. For example, secondary science education programs could focus on developing topic-specific PCK in prospective teachers. Many prospective

science teachers know their content well, but they have not learned how to transform or translate that knowledge into meaningful units for instruction. By focusing on topic-specific examples, laboratories, and demonstrations, prospective secondary teachers can focus and develop specific strategies. What is necessary is the effective use of exemplary models of science teaching within topics that can later be transferred to another topic or domain. They can then apply these strategies to other topics and domains based upon their content backgrounds.

Implications for Teacher Education and Future Research

Directly or indirectly, teacher education programs will benefit from further pedagogical content knowledge research. One obvious area of future research would be to focus on discovering each structure of subject matter in each particular area. Another area that will raise the researchers' interest represents the ways in which we can match subject matter structures with the characteristics of the students.

The error pattern analysis in mathematics and reading talks about the problems students have when they acquire knowledge and that teacher should try to solve these problems by finding the best subject matter structure that can serve to solve the problems that students encounter when they learn.

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For the Masters of Arts in Education: Teaching Degree

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at the University of Northern Iowa

Cedar Falls, Iowa 50614

On

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